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Sizing of Microparticles from Angular Scattering Ratio

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This technical note deals with light scattering measurements for sizing of micrometer-scale particles in a suspension.

Angular Scattering. The intensity of light scattered from a single spherical particle, Fig 1(a), has strong angular dependence, as illustrated in Fig 1(b). Notice that θ is measured clockwise.

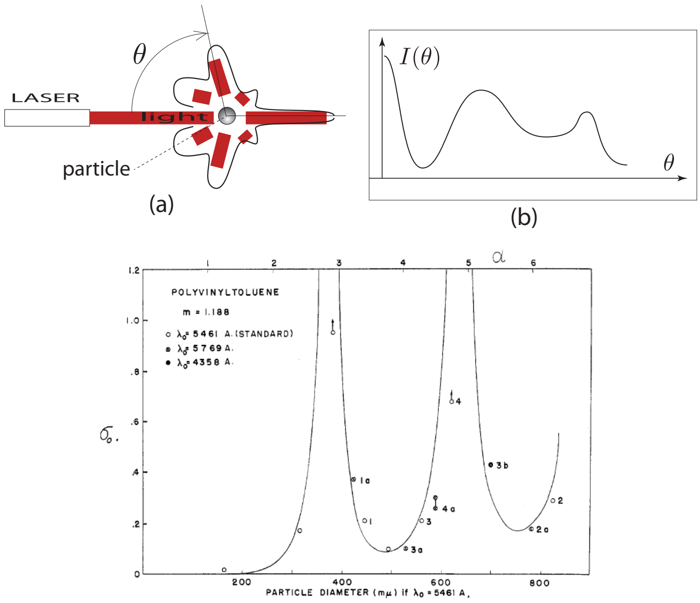

FIGURE 1. (a),(b): laser light scattered from a spherical particle has a strong dependence on angle θ. The ratio of intensities for two fixed angle values (c) is a strongly varying function of particle size.

This effect is also seen for a suspension of particles, provided the average interparticle distance is much larger than the particle diameter d, that is, provided $d\rho^{1/3} \ll 1$, where ρ is the particle density.

The ratio $\sigma = I(25°)/I(90°)$ of scattered light intensity measured at two fixed angles $\theta = 25°$ and $\theta = 90°$ is strongly dependent on the *electrical size* d/λ of the particle. Here, λ is the wavelength of the incoming monochromatic light. Fig 1(c) is from reference [2], and it shows an example of the intensity ratio σ as function of particle diameter. For particles with the size parameter $d\pi/\lambda$ in the approximate range from 0.1 to 100, Mie theory is applicable in the description and the numerical computation of the scattered light.

In certain intervals of particle diameter the intensity ratio σ is a monotone function of particle size, and it can therefore be used as an accurate and unambiguous measure of the diameter of the suspended particles.

Fig 2(a) shows the numerically computed intensity ratio σ in the restricted range of particle diameter from $d = 0.8\mu$m to $d = 1.45\mu$m. We used Scott Prahl's online Mie scattering calculator [3].

The illumination is unpolarised and with a fixed free-space wavelength $\lambda = 650$nm. The spherical particles have refractive index 1.4, and are suspended in tap water (refractive index 1.0114). The particle concentration is on the order of $\rho = 10^{17}$ spheres/m^3. It is seen that this mode of measurement allows the unique determination of particle diameter in the dynamical range 800nm to 1.45μ, and also that the numerically simulated intensity ratio σ approximately attains the value 1 at particle diameter 1μm, as observed experimentally by TurbiSense.

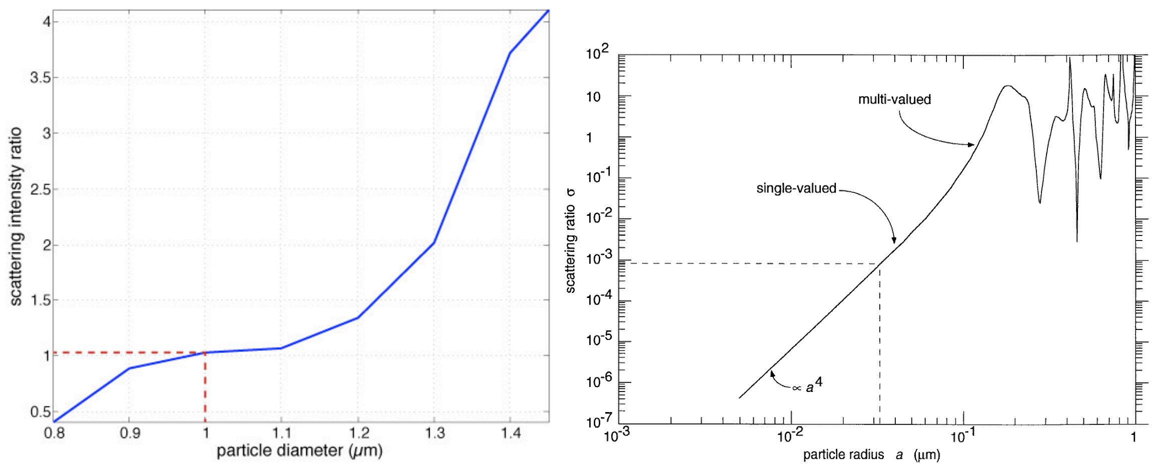

Figure 2. (a) Intensity ratio $\sigma = I(25°/I(90°$ for particle diameter from 0.8μm to 1.45μm and unpolarised illumination. The intensity ratio is a clear indicator of particle size. (b) Intensity ratio $I_{\text{parallel}}(90°)/I_{\text{perpendicular}}(90°)$ for particle diameter from 0 to 0.2λ.

For broader range sizing electrically small particles, we recommend working with polarised light. Fig 2(b) is from [4] and it shows an example of the ratio of the parallel and perpendicularly polarised scattered light intensity measured at one single angle, $\theta = 90°$. Here, the particle diameter is reconstructible in the range from 0 to approx. 0.2λ, which in our case would be the interval 0nm to 130nm. The equipment currently used by TurbiSense should be easily modifiable to use polarised light.

References

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